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August 28, 2000

Attorney Docket No.: 06618/692001/CIT3277

Box Patent Application
Commissioner for Patents
Washington, DC 20231

Presented for filing is a new patent application claiming priority from a provisional patent application of:

Applicant: LAWRENCE CARY GUNN, III

Title: OPTICAL SYSTEM USING ACTIVE CLADDING LAYER

Enclosed are the following papers, including those required to receive a filing date under 37 CFR 1.53(b):

	Pages
Specification	8
Claims	3
Abstract	1
Declaration	[To be Filed at a Later Date]
Drawing(s)	3

Enclosures:

— Postcard.

Under 35 USC §119(e)(1), this application claims the benefit of prior U.S. provisional application serial no. _______________, filed August 27, 1999.

This application is entitled to small entity status. A small entity statement will be filed at a later date.

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Derek W. Norwood
Typed or Printed Name of Person Signing Certificate

Basic filing fee	$0
Total claims in excess of 20 times $9	$0
Independent claims in excess of 3 times $39	$0
Fee for multiple dependent claims	$0
Total filing fee:	$0

No filing fee is being paid at this time.

If this application is found to be incomplete, or if a telephone conference would otherwise be helpful, please call the undersigned at (858) 678-5070.

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Respectfully submitted,

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Reg. No. 32,030
Enclosures
SCH/keh
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Attorney's Docket No.: 06618/692001 / CIT-3277

APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: OPTICAL SYSTEM USING ACTIVE CLADDING LAYER

APPLICANT: LAWRENCE CARY GUNN, III

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OPTICAL SYSTEM USING ACTIVE CLADDING LAYER

This application claims the benefit of U.S. Provisional Application No. _______________ filed on August 27, 1999.

Background

It is known to use optical resonators and fibers for many purposes.

Optical resonators can take many different shapes including Bragg reflective waveguide cavities, Fabry-Perot cavities, ring resonators, and disk resonators. Each of these elements includes a resonant cavity which supports wavelength dependent resonance - the ability to constructively interfere with the optical energy of the resonant wavelength. Once optical energy of the specified resonant wavelength, e.g., light, is coupled into the cavity, the light may remain in the cavity and move over long distances within the cavity in random directions.

SUMMARY

The present application teaches a special kind of optical resonator which includes an "active" cladding, causing optical amplification.

In a preferred embodiment, optically active cladding components are added to optical components, e.g., integrated waveguides and optical resonator structures. Applications may include optical filtering, optical switching, and optical amplification.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will now be described in detail with reference to the accompanying drawings wherein:

Figure 1 shows a disk resonator being used as a filter;

Figure 2 shows a cross-sectional view of a disk resonator being used with an optically active cladding; and

Figure 3 shows the system configured as a rotation detector.

DETAILED DESCRIPTION

Figure 1 shows a resonator being used as an optical element with an adjacent waveguide. While any resonator can be used, as noted above, the detailed description specifically refers to a disk resonator, which may be considered as one preferred way to make this system, due to its ease of manufacture and use. It should be understood that the term "resonator" as used herein, however, refers to any of the resonators referred to above.

Figure 1 shows a disk resonator being used as a routing/amplification element. Light in 110 includes a plurality of wavelengths λ_{01}, λ_{02}, λ_{03}, λ_{04} … λ_n. The light in 110 is coupled to an optical waveguide 115 that passes the light. The light out 120 has different characteristics than the light in. In the shown embodiment, the resonator 130 is resonant with the frequency λ_1 and thereby forms a filter for λ_1. A second waveguide 140 is placed in proximity with the resonator 130. The waveguide 140 produces a light output 145 corresponding to filtered out λ_1. The light output 120 of the first waveguide 110 includes all of the frequencies except λ_1.

If the power losses in the resonator and fiber are ignored, then the output power of the second waveguide is the same as the power coupled out of the original waveguide for that wavelength. Of course, some losses always occur. Loss mechanisms include insertion losses, waveguide and cladding material absorption losses, surface scattering losses, and device geometry induced coupling and scattering losses.

According to the present system, gain is added to the resonator system. Figure 2 shows how the gain is added. The resonator 130 is modified to include an active cladding system 135. An exemplary active cladding system may be an erbium doped silicon dioxide material 210. The erbium doped dioxide

is pumped with a pump laser to cause amplification using known effects.

The waveguide structure itself can be any material that has a higher index of refraction than the cladding. The waveguide structure must also be transparent to wavelengths that are produced in the active cladding. In the specific material example that is given, an erbium doped cladding could be used with a semiconductor material, such as a silicon or gallium arsenide waveguide. The waveguide core material which is used does not need to be optically active. Since a semiconductor material can therefore be used for the optical part, other silicon processing techniques can be used on that material. The silicon, for example, can include active microelectronic structures, or can be processed by micromachining techniques.

The cladding region requires a gain medium of sufficient length to allow optical gain. A pump source 250 for the gain medium 240 is also necessary. It is known to use erbium doped fiber amplifiers. Erbium doped fiber amplifiers may be pumped with 980 nanometer or 1480 nanometer light. These pumping devices must be relatively long, usually about one meter, in order for the light to effectively interact with the erbium-doped material. While this is still one option, the way that a resonator operates can be used to allow operation without

requiring quite so long an overlap. In the integrated optics domain, gain can be added to the resonant cavities, thereby taking advantage of the increased effective path length due to the high Qs of the resonator. In this way, the interaction of the light with the amplification medium is increased. This is done by forming an active cladding layer on the resonator waveguide surface and thereby introducing a cladding based gain medium to the resonator, in order to amplify the resonant light.

Another factor which needs to be addressed is the gain of the optical amplifier. When an active waveguide core is used, this gain is dependent on the confinement factor of the waveguiding material. For example, the gain may be proportional to the power that is contained in the cladding. This proportionality, however, may be non-linear. However, the gain of the waveguide structures may also be dependent on factors that determine the amount of power in the cladding such as geometry and refractive index of the material. The active resonator which includes gain therein. This may have different applications which are described herein. These applications may also vary depending on the amount of gain which is provided by the doping. There is a certain threshold gain which can be determined by experimentation. Below that gain, the amount of amplification that occurs may not be

useful for many purposes. Above the threshold, however, the active material may spontaneously omit. This can bootstrap the cavity to an appropriate photon density which produces stimulated emission. The stimulated emission may be analogous to lazing, hence forming a laser cavity from an optical resonator. However, below the threshold, effects may also be useful for filtering optical signals, e.g., forming an add/drop system only to the frequency of interest to a specific waveguide. Unlike other systems, this system can use semiconductor materials. Since an optically inactive material such as silicon may be used for the core waveguide, this provides flexibility in the kinds of material that can be used in both over the threshold and under the threshold applications.

Yet another application is in rotation sensing as shown in Figure 3. The Sagnag effect as used in a ring laser gyroscope relies on the interference of counter propagating beams. A resonator 310, such as a disk resonator, is driven as described above operate over the lazing threshold. Light from source 300 is coupled via 305 to form counter-propagating light in many different directions within the resonator 310. If the disk is rotated, the counter propagating light will interfere based on the rotation according to the Sagnag affect. The rate of rotation can then be sensed as a function

of the intensity coupled out of the resonator to the adjacent waveguide 315, and a sensing element 320.

Another rotation sensor can be formed based on the wavelength dependence of the resonator. When the resonator is operated as a filter, its wavelength dependence will vary based on rotation. In this embodiment, source 300 is a frequency tuned stabilized light source. The intensity of the coupled light then varies as a function of the rotation of the resonator. If the light source has a smaller line width in the passband of the filter, and is slightly detuned, the response in the positive and negative direction can be made linear.

Another embodiment uses the same feature without an active cladding. However, in this alternative embodiment without the active cladding, the gain may be small.

Yet another embodiment uses a partially coupled concentric ring resonator. This effect is even further enhanced by this system, since a longer path length and longer cavity photon lifetime is provided. Some phase modulation or tuning of the effective length may be necessary in this system.

Although only a few embodiments have been disclosed in detail above, other modifications are possible. For example, although we have only described certain resonators, other

resonators are also possible. Other materials can be used as the active layer. In addition, other applications of the laser system may be predictable.

All such modifications are intended to be encompassed within the following claims, in which:

What is claimed is:

1. An optical structure, comprising a resonator structure having an optical portion forming a core, and a cladding layer formed of an active material, said cladding layer configured to amplify optical energy in said core.

2. A device as in claim 1, further comprising a pump laser, optically pumping said cladding layer.

3. A system as in claim 2 wherein said cladding layer is an erbium doped portion of material.

4. A system as in claim 2 wherein an effective path length of the pumping is based on an optical path length that is increased by the amplification.

5. A system as in claim 1 wherein said optically active portion is formed of semiconductor material.

6. A system as in claim 5 wherein said semiconductor material is one of silicon or gallium arsenide.

7. A device as in claim 1 wherein said pumping laser pumps the system to produce spontaneous emission from the ore.

8. A method, comprising:

introducing light into an optical resonator; and

amplifying the light in the optical resonator.

9. A method as in claim 8 wherein said amplifying comprises amplifying the light until spontaneous emission is caused.

10. A method as in claim 8 wherein said amplifying comprises adding a pump laser to a doping in a core portion of the optical resonator.

11. A method as in claim 8 wherein said resonator is a of the disk resonator.

12. A method as in claim 8 wherein said resonator uses silicon as its optically active layer.

13. A method of sensing rotation, comprising:

introducing light into an optical resonator;

rotating said optical resonator; and

detecting a wavelength dependence caused by said rotation to detect some characteristic of said rotation.

14. A method as in claim 13 wherein said detecting comprising detecting an intensity.

15. A method as in claim 13 wherein said detecting comprises detecting a wavelength.

16. A laser comprising an optical resonator, with an active core material, and a pump laser which drives said active clad material until said optical resonator spontaneously emits light.

Attorney Docket No. 06618/692001/CIT-3277

ABSTRACT

An optical resonator is described which includes an active cladding material, the active cladding material enabling optical amplification.

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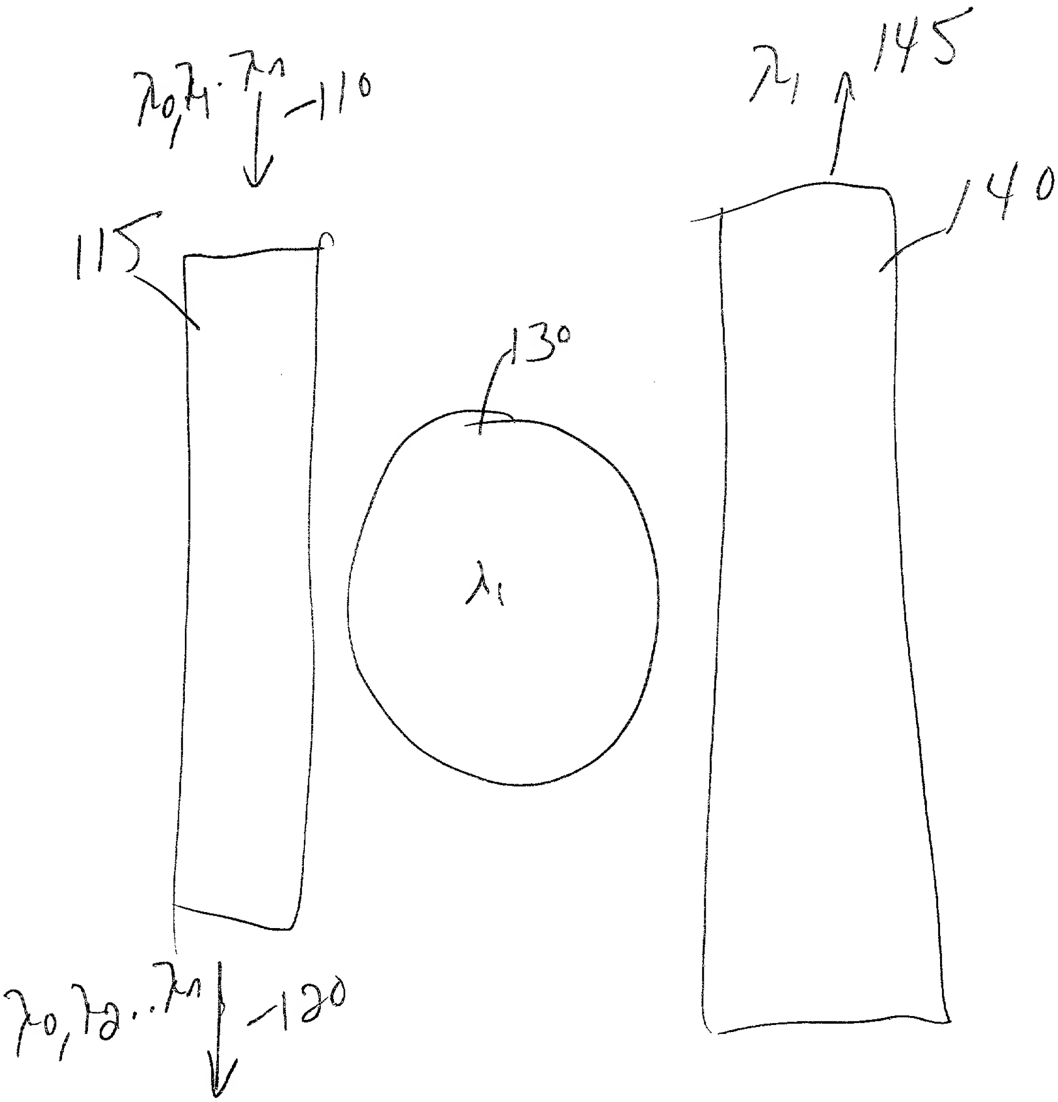
$\lambda_0, \lambda_1 \cdot \lambda_n$
110
115
130
λ_1
λ_1
145
140
$\lambda_0, \lambda_2 .. \lambda_n$
120

FIG 2

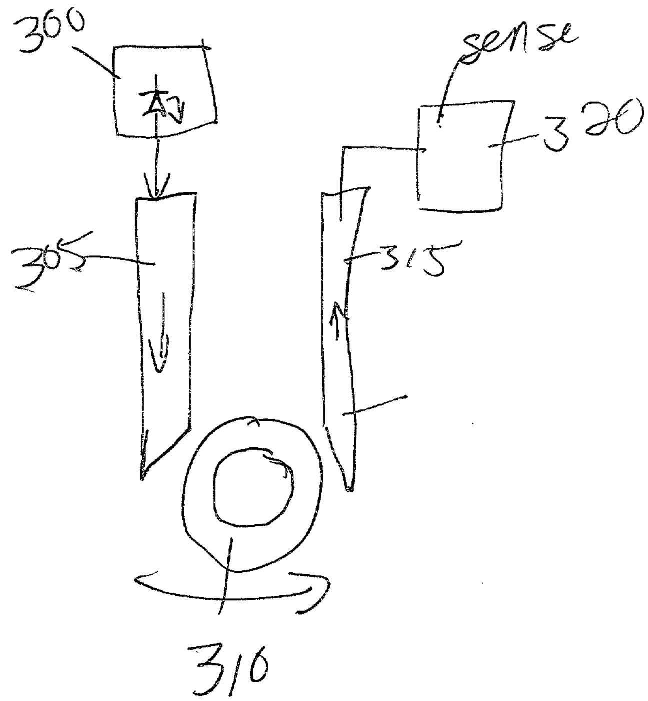

FIG 3